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val offset curve mode, the angle of displacement of machine central longitudinal axis 47 at the end of the cutting stroke from its position at the beginning of the cutting stroke is approximately 3—5° in a machine approximately 5.5m (18 feet) long with a cutting wheel diameter of approximately 3.7m (12 feet) and having a 0.91 m (3 foot) center of radius of curvature of dome is rear pivot point in closed position in this embodiment.

Claims

1. A tunnel boring machine (30) for boring a tunnel (31) having an end face (33) and a peripheral wall (34) including a floor portion (36), a ceiling portion (35), and opposing sidewall portions (37, 38) spaced from a central longitudinal tunnel axis (32); the tunnel boring machine including:

rotatable cutting wheel (66) at the front end of the machine having a central axis of rotation extending generally longitudinally within the tunnel, said cutting wheel being adapted to be selectively located at a desired position and held against the tunnel face during rotation for cutting material away from the tunnel face to elongage the tunnel and extend the central longitudinal tunnel axis in a selected direction;

a diametrically compact machine body (42) having a central longitudinal machine axis (47) positioned coaxially with said cutting wheel central axis of rotation for supporting various machine components having a forward end positioned proximal the tunnel face and a rear end positioned distal the tunnel face;

at least one thrust rod (44) operatively associated with said cutting wheel (66) and said machine body (42) and being axially extendible parallel to said longitudinal machine axis for moving the cutting wheel (66) forwardly relative said machine body (42) during a cutting stroke; a cutter drive unit (71—75) operatively connected to said rotatable cutting wheel (66) for selectively causing rotation thereof;

a laterally extendible and retractable, rear end, tunnel wall engaging assembly for locating and holding the rear end portion of the machine body between opposite tunnel sidewall portions;

a laterally extendible and retractable, front end, tunnel wall engaging assembly mounted on a front end portion of the machine (30) for locating and holding said front end portion of the machine (30) between the opposite tunnel sidewall portions;

the invention being characterised by the following features:

said laterally extendible and retractable, rear end, tunnel wall engaging assembly being pivotally attached to said rear end portion of said machine body (42), said machine body being pivotable about a rear end pivot axis (125) which remains fixed relative to said machine body (42) and relative to said tunnel peripheral wall (34) during a curved cutting stroke and which is located proximate the rear most portion of said machine (30);

said laterally extendible and retractable, front end tunnel wall engaging assembly being selectively extendible and retractable in a direction generally perpendicular to said rear pivot axis (125) and perpendicular to said longitudinal machine axis (47) for providing selective pivotal movement of said machine body about said fixed rear pivot axis (125).

2. A tunnel boring machine according to claim 1, further characterised by:

said at least one thrust rod (44) being extendible and retractable from said machine body forward portion and being always located entirely forwardly of said rear pivot axis (125) whereby a relatively axially compact machine (30) is provided, said machine body (42) being movable forwardly in said tunnel between cutting strokes through retraction of said thrust rod into said machine body.

3. A tunnel boring machine according to claim 1 or 2, characterised by said machine body comprising a unitary, continuous, relatively axially compact body having said front end tunnel wall engaging assembly fixedly mounted on a forward end portion thereof.

4. A tunnel boring machine according to claim 1, 2 or 3, characterised in said at least one thrust rod (44) having a central longitudinal axis which is coaxial with said central longitudinal machine axis (47).

5. A tunnel boring machine (30) according to any one of claims 1 to 4, characterised in that said rear tunnel wall engaging assembly comprises:

opposite extendible and retractable rear arms (18, 20) for selective engagement and disengagement with the tunnel sidewall, said opposite rear arms having a rear arm axis (146) intersecting said cutting wheel axis of rotation (47), said rear arm axis being pivotable about a machine rear vertical axis (125); said rear vertical axis (125), said rear arm axis (146) and said cutting wheel axis of rotation (47) intersecting at and defining a rear machine pivot point (150); said machine body (42) being selectively pivotal at said rear end portion thereof about both said rear arm axis (146) and said machine rear vertical axis (125).

6. A tunnel boring machine (30) according to claim 5, characterised in that said rear tunnel wall engaging assembly further comprises an extendible and retractable rear leg (132) having a support wheel (130) mounted thereon, said rear leg being extendible and retractable along said machine rear vertical axis (125) and being capable of rollingly supporting a rear end portion of said machine body (42).

7. A tunnel boring machine (30) according to claim 6, characterised in that said front end tunnel wall engaging assembly comprises:

opposite laterally extendible and retractable forward arms (12, 14) for selective engagement and disengagement with the tunnel sidewall (37, 38), said opposite front arms (12, 14) being coaxial with a forward arm axis (156) intersecting said cutting wheel rotation axis (47) and substantially perpendicular thereto; and

a forward vertically extendible and retractable leg (16) fixedly attached to said machine body and coaxially aligned with a forward vertical axis (160) intersecting said cutting wheel rotation axis (47) and perpendicular thereto; said forward leg having a base plate (94) at one end thereof for supportingly engaging the tunnel floor (36), said base plate (94) being swivelly mounted on said forward vertical leg (16) for angularly displaceable movement relative thereto and having lateral slide means (95) for allowing laterally shifting movement of said forward vertical leg (16) relative a floor engaging portion of said base plate (94).

8. A tunnel boring machine according to claim 7, characterised in that said rear arms (18, 20) comprise rear arm control apparatus (118, 120) for extending said rear arms (18, 20) into tunnel wall gripping contact at the beginning of a cutting stroke and for retracting said rear arms at the end of a cutting stroke in straight ahead, horizontally curved, or vertically curved modes of operation; in that said rear arm control apparatus further comprises adjusting means (26, 28) for pivoting said rear arm axis (146) into perpendicular relationship with the tunnel longitudinal axis (32); in that said rear leg (132) comprises rear leg control means (134) for retracting said rear leg means prior to the beginning of a cutting stroke and for extending said rear leg after the completion of a cutting stroke to support the rear end of said machine body (42) during forward movement thereof betwen cutting strokes in straight ahead, horizontally curved or vertically curved modes of operation; in that said forward arms (12, 14) comprise forward arm control apparatus (102, 104) for extending said forward arm into wall gripping contact at the beginning of a cutting stroke and retracting said forward arm at the end of of a cutting stroke in a straight ahead mode of operation, and for placing said forward arms into continuous steering contact with the tunnel wall (37, 38) wherein one portion of said forward arms is continuously extended during a cutting stroke and an opposite portion of said forward arms is continuously retracted during said cutting stroke and for retracting said forward arms (12, 14) form wall engaging contact at the end of said cutting stroke in the horizontally curved cutting mode of operation, and for extending said forward arms into equally extended sliding contact with the tunnel wall (37, 38) during a cutting stroke and for retracting said forward arms (12, 14) from sliding contact with the tunnel walls at the end of said cutting stroke in a vertically curved mode of operation; in that said forward leg (16) comprises forward leg control apparatus (106) for retracting said forward leg at the end of a cutting stroke to place said cutting wheel means (66) in self supporting engagement with the tunnel sidewall and for extending said forward leg means (16) to raise the cutting wheel (66) into vertical alignment with the longitudinal axis (32) of the tunnel and to retain it in vertical alignment with the tunnel longitudinal axis during the cutting stroke in straight ahead and horizontally curved modes of operation and to continuously vertically raise or lower the cutting wheel relative the tunnel longitudinal axis (32) during the cutting stroke and in said vertically curved mode of operation; and in that said thrust arm (44) comprises thrust arm control apparatus (42) for extending said thrust arm (44) relative said machine body for advancing said cutting wheel (66) during a cutting stroke and for retracting said thrust arm relative said machine body for advancing said machine body between cutting strokes.

9. A method for boring an elongate curved tunnel (31) having a central longitudinal axis (32) and having tunnel cross-sections each having a horizontal axis (41) oriented generally perpendicular to the direction of gravitational force and intersecting the central longitudinal axis and having a vertical axis (45) intersecting the central longitudinal axis (32) and the horizontal axis (41) and perpendicular to both, characterised in that the steps comprise:

a) providing a tunnel boring machine (30) having an axially and diametrically compact main body (42) with a thrust means (44) extendibly and retractably mounted on said main body and movable parallel to a machine longitudinal axis (47), and having a rotatable cutter wheel (66) attached to the thrust means with an axis of rotation (47) coaxial with the machine central longitudinal axis and having forward horizontal and forward vertical positioning devices (12, 14, 16) and having rear horizontal and rear vertical positioning devices (18, 20, 132) coupled to the main body at a fixed rear machine pivot point (150);

b) positioning the rear machine pivot point (150) of the main body (42) lying on the machine longitudinal axis (47) at a point on the tunnel longitudinal axis (32) through the use of the rear horizontal and rear vertical positioning devices (18, 20, 132);

c) fixing the rear pivot point (150) in linearly non-displaceable relationship with respect to the tunnel longitudinal axis (32) by selectively extending the rear horizontal positioning devices (18, 20) into gripping contact with the tunnel wall;

d) retracting the rear vertical positioning device (132) to a non-interfering position relative to the tunnel surface;

e) positioning a forward point (170) on the machine longitudinal axis at a perdetermined position with the tunnel by the use of the forward horizontal and forward vertical positioning devices (12, 14, 16);

f) placing the cutting wheel (66) in engaging contact with the tunnel face by extension of the elongated thrust means (44) during a cutting stroke from a retracted start of stroke position to an extended end of stroke position;

g) simultaneously with step f), pivoting the main body (42) about the rear machine pivot point (150) by use of at least one of the forward horizontal positioning device (12, 14) and the forward vertical positioning device (16);

h) at the end of the cutting stroke, lowering the cutting wheel (66) onto the tunnel floor by retraction of the forward vertical positioning device (16);

i) extending the rear vertical positioning device (132) to support a rear portion of the main body (42);

j) disengaging the rear horizontal positioning device (18, 20) from gripping engagement with the tunnel wall;

k) moving the main body (42) in a forwardly direction by retracting of the thrust means (44); and

l) repeating the steps a) through k) until a tunnel curved position is completed.

Patentansprüche

1. Tunnelbohrmaschine (30) zum Bohren eines Tunnels (31) mit einer Endfläche (33) und einer Umfangswand (34) mit einem Bodenabschnitt (36), einem Deckenabschnitt (35), gegenüberliegenden Seitenwandabschnitten (37, 38), die im Abstand von einer zentralen Tunnellängsachse (32) angeordnet sind; wobei die Tunnelbohrmaschine folgendes enthält:

ein rotierbares Schneiderad (66) an vorderen Ende der Maschine mit einer zentralen Drehachse, die sich im wesentlichen in Längsrichtung innerhalb des Tunnels erstreckt, wobei das Schneiderad dazu vorgesehen ist, um wahlweise an einer gewünschten Position angeordnet und gegen die Tunnelstirnfläche gehalten zu sein während der Drehung zum Wegschneiden von Material von der Tunnelfläche, um den Tunnel zu verlängern und die zentrale Tunnellängsachse in einer ansgewählten Richtung auszudehnen;

einen diametralen Maschinenpreßkörper (42) mit einer zentralen Maschinenlängsachse (47), koaxial angoerdnet zur der zentralen Schneideraddrehachse zum Tragen verschiedener Maschinenteile, mit einem vorderen Ende, welches in der Nähe der Tunnelstirnfläche angeordnet ist und einem hinteren Ende, welches entfernt von der Tunnelstirnfläche angeordnet ist;

mindestens einen Stoßstab (44), der dem Schneiderad (66) und dem Maschinenkörper (42) operativ zugeordnet ist und der axial parallel zu der Maschinenlängsachse zum Bewegen des Schneiderades (66) nach vorne relativ zu dem Maschinenkörper (42) während eines Schneidevorganges ausfahrbar ist; eine Schneideantriebseinheit (71—75), die operativ mit dem drehbaren Schneiderad (66) zum wahlweisen Bewirken seiner Drehung verbunden ist;

eine seitlich ausfahr- und einziehbare hintere Tunnelwandineingriffsanordnung zum Anordnen und Halten des hinteren Endabschnittes des Maschinenkörpers zwischen gegenüberliegenden Seitenwandabschnitten des Tunnels;

eine seitlich ausfahr- und einziehbare vordere Tunnelwandineingriffsanordnung, welche an einem vorderen Endabschnitt der Maschine (30) angeordnet ist zum Anordnen und Halten des vorderen Endabschnittes der Maschine (30) zwischen gegenüberliegenden Seitenwandabschnitten des Tunnels;

gekennzeichnet durch die folgenden Merkmale:

die seitlich ausfahr- und einziehbare hintere Tunnelwandineingriffsanordnung ist mit dem hinteren Endabschnitt des Maschinenkörpers (42) gelenkig verbunden, der Maschinenkörper ist um eine Drehachse (125) am hinteren Ende drehbar, die bezüglich dem Maschinenkörper (42) und bezüglich der Tunnelumfangswand (34) während eines Kurvenschneidevorganges fest bleibt, und die nahe des äußersten hinteren Anschnittes der Maschine (30) angeordnet ist;

die seitlich ausfahr- und einziehbare vordere Tunnelwandineingriffsanordnung ist wahlweise ausfahrbar und einziehbar in einer Richtung im wesentlichen senkrecht zu der hinteren Drehachse (125) und zu der Maschinenlängsachse (47) zum Ergeben einer gewählten Drehbewegung des Maschinenkörpers um die feste hintere Drehachse (125).

2. Tunnelbohrmaschine nach Anspruch 1, gekennzeichnet durch mindestens einen Stoßstab (44), der von dem vorderen Abschnitt des Maschinenkörpers ausfahrbar und einziehbar ist und der jeweils insgesamt vor der hinteren Drehachse (125) angeordnet ist, wodurch sich eine relativ axiale preßmaschine (30) ergibt, wobie der Maschinenkörper (42) in dem Tunnel zwischen Schneidevorgängen durch Einziehung des Stoßstabes in den Maschinenkörper nach vorwärts bewegbar ist.

3. Tunnelbohrmaschine nach Anspruch 1 oder 2, gekennzeichnet durch einen Maschinenkörper, der einen einheitlichen kontinuierlichen, relativ axialen Preßkörper aufweist mit einer vorderen Tunnelwandineingriffsanordnung, die an seinem vorderen Endabschnitt fest angeordnet ist.

4. Tunnelbohrmaschine nach einem der Ansprüche 1, 2 oder 3, dadurch gekennzeichnet, daß mindestens ein Stoßstab (44) eine zentrale Längsachse aufweist, die koaxial zu der zentralen Maschinenlängsachse (47) ist.

5. Tunnelbohrmaschine (30) nach einem der Ansprüche 1 bis 4, dadurch gekennzeichnet, daß die hintere Tunnelwandineingriffsanordnung folgendes aufweist:

gegenüberliegende ausfahr- und einziehbare hintere Arme (18, 20) zum wahlweisen Eingreifen und Loslösen mit der Tunnelseitenwand, wobei die gegenüberliegenden hinteren Arme eine hintere Armachse (146) aufweisen, die die Schneideraddrehachse (47) kreuzt, wobei die hintere Armachse um die senkrechte hintere Achse (125) drehbar ist; wobei die hintere vertikale Achse (125), die hintere Armachse (146) und die Schneideraddrehachse (47) einen hinteren Maschinengelenkpunkt (15) bilden und kreuzen; wobei der Maschinenkörper (42) an seinem hinteren Endabschnitt umd die hintere Armachse (146) und die hintere senkrechte Maschinenachse (125) selektiv drehbar ist.

6. Tunnelbohrmaschine (30) nach Anspruch 5, dadurch gekennzeichnet, daß die hintere Tunnelwandineingriffsanordnung weiterhin einen aus-